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A body located in a flux of solar radiation absorbs, reflects, /21 and transmits this energy in specific ratios. At the same time it itself radiates and gives off heat by convection into the surrounding space.

Here we are concerned with the case where the absorbed energy is converted into heat which is removed for useful work and is partially lost. The percentage of useful heat at a given temperature of the surface receiving rays may be changed by using different coverings, applying them on the surface to be heated by the rays or placing them in front of this surface.

Such measures are intended to decrease or increase the heat losses from the body to be heated. Thus, for example, covering the surface of a boiler of a solar water heater with black paint, we increase the heat absorption of the boiler, however at the same time self-losses into the surrounding medium are increased. Or, placing a glass sheet in front of such a boiler we decrease the heat losses from convection and somewhat lower radiation losses (the glass here plays the role of a screen). However, such protective glass increases losses by the solar device as a result of the reflection of radiation from the surfaces of the glass and the partial absorption of the radiation by the glass.

Comparatively recently methods were proposed for increasing the efficiency of solar devices by means of using special selective coatings which are applied on the solar ray receiver and/or on the protective glass [1].

*Numbers in righthand margin indicate pagination of foreign text.

Approximate calculations conducted by many researchers showed that under specific conditions the efficiency (η) of several solar installations may be significantly increased by such a means. In [2] it is indicated, for example, that the application of selective coatings on the surface of the boiler of a solar water heater increases the efficiency (η) of the latter to 50% with a boiler temperature Θ_b = 80° C with the selective parameters A = 0.9 and ε = 0.3 instead of the η = 35-38% of an ordinary blackened surface with the parameters A = ε = 0.95 at the same boiler temperature Θ_b = 80° C. Over the course of time very many different selective coatings have been developed for glasses and the boiler of a solar radiation receiver [1,2,3,4,5,6,7].

Since the value of the different coatings is not identical, /22 the selection of the type of coating used must be made by means of variant calculations.

We developed a method for calculating solar installation using selective materials and performed numerous calculations of actual installations with certain coatings under different operating conditions.

The results of several of our investigations are presented below in the form of graphs on which the thermal balances of solar receivers of different construction. They showed, for example, that a solar water heater with a flat ordinary blackened boiler (ε_b = 0.88; A_b = 0.9) with a single glass shield and very good insulation (thickness of insulation δ = 10 cm) in the case of solar radiation fluxes I = 400, 600, and 800 kcal/m^{2}h and with a temperature of the surrounding environment Θ_{env} = 30° C may heat the water to 92, 114, and 140° C, respectively, with an efficiency equal to zero (equilibrium temperature). In the case of heating water to 60° C their efficiency will be 45, 55, and 62%; to 70° C, 31, 46, and 54%; to 80° C, 18, 36, and 48%, respectively. To boil water in such a heater is possible only in the case of radiation of not less than 600 kcal/m^2h; in this case the efficiency will be equal to 15%.

The use of the selective coatings developed up to the present time expands the temperature range of operation of heaters, and the efficiency of heating water at the same temperatures, as in an ordinary (without selective coatings) heater will be significantly higher. Thus, for example, with selective coating (also single glass shielding) of the boiler receiving surface—polished copper with a cobalt dioxide film (Co_2O_3, ε_b = 0.24; A_b = 0.93)—in the case of a radiation of 400, 600, and 800 kcal/m^2h the efficiency at temperatures which are equilibrium for an ordinary boiler, will here be 29, 31, and 32%, respectively. In the case of heating water to 60° C with the same radiation the efficiency will be 58, 66, and 70%, respectively; in the case of heating to 70 and 80° C, 50, 60, and 66 and 41, 54, and 61%. In the case of boiling water in such a boiler the efficiency in the case of radiation of 400, 600, and 800 kcal/m^2h will be 21, 41, and 51%, respectively.

Fig. 1. Influence of the boiler temperature on the thermal balance of a solar radiation receiver. The ordinates of the field: 1- energy losses due to reflection of rays from the glass; 2- energy losses due to absorption of rays by glass; 3- energy losses due to reflection from boiler surface; 4- energy losses due to radiation from boiler; 5- energy losses due to convection through the air space; 6- energy losses through the bottom and side walls; 7- useful energy.

For water heaters with a flat boiler with a single glass shield in relation to the gain in efficiency the case where the protective glass is coated with a tin dioxide film (SnO_2, ε_{gl} = /23
= 0.02) and the boiler receiving surface, polished copper coated with a cobalt dioxide film (Co_2O_3, $\varepsilon_b = 0.24$; $A_b = 0.93$), is more optimal in the variants considered.

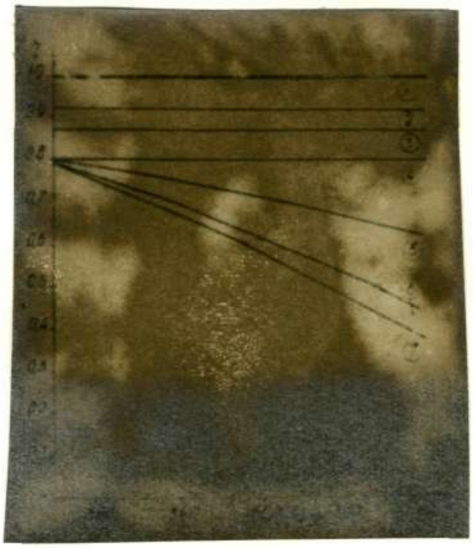

Fig. 2. Designations the same as on Fig. 1.

Fig. 3. Designations the same as on Fig. 1.

In this case the temperature range is even greater than in the last case. Actually, with a radiation of 400, 600, and 800 kcal/m^2h respectively at temperatures of 92, 114, and 140° C, the efficiency of such a water heater equals 53, 55, and 57%, while these temperatures are equilibrium for a receiver with an ordinary boiler. Or in the case of heating water to a temperature of 60, 70, and 80° C with solar radiation of 400 kcal/m^2h the efficiency equals 70, 64, and 59%, and with radiation of 600 and 800 kcal/m^2h 74, 70, 67 and 77, 74, 71%. If such a heater were used for boiling water, then its efficiency, in the case of a radiation of 400, 600, and 800 kcal/m^2h, would be equal to 48, 60, 66%, respectively.

The results of calculations of the thermal balance of a solar radiation receiver with a single glass shielding and different receiving surfaces for $\Theta_{env} = 30°$ C are given in the table. They may serve as a basis for economic calculations on the application of solar water heaters.

Figures 1, 2, and 3 show graphs of the thermal balance of three different surfaces in the case of $\Theta_{env} = 30°$ C and I = 800 kcal/m^2h. Here it is possible to see the individual components of the heat losses.

Table 1. Efficiency (%) in the case of different heating temperatures and with $\Theta_{env} = 30°$ C, I = 800 kcal/m^2h.

Type of boiler receiving-surface coating	Heating temperature (t°C)							
	40	60	80	90	100	110	120	130
	Efficiency (%)							
Coated with simple black paint	73.5	61	47.5	40	32	23.5	14.5	12
Polished copper sheeting, coated with cobalt dioxide	78	70	61	56.5	51	46	40.5	35
Polished molybdenum, coated with a double film—magnesium oxide and metallic molybdenum	57.5	51	44	40	36.5	32.5	28.5	24.5
Polished aluminum sheeting coated with a copper oxide film	70.5	64	56	52	48	44	39.5	35
Polished copper sheeting coated with a layer of cobalt dioxide, and protective glass coated with a layer of tin dioxide	80	76.5	71.5	69	66.5	63.5	61	58

Table 2. Efficiency (%) in the case of different heating temperatures and with Θ_{env} = 30° C, I = 600 kcal/m^{2}h.

Type of boiler receiving-surface coating	Heating temperature (t°C)							
	40	60	80	90	100	110	120	130
	Efficiency (%)							
Coated with simple black paint	72	55	36	26	15	4	-	-
Polished copper sheeting, coated with cobalt dioxide	77	66	54	47	41	34	27	29
Polished molybdenum, coated with a double film—magnesium oxide and metallic molybdenum	57	48	39	34	29	23	18	13
Polished aluminum sheeting coated with a copper oxide film	69	60	50	45	39	34	28	22
Polished copper sheeting with a layer of cobalt dioxide, and protective glass coated with a layer of tin dioxide	80	74	68	64	60	57	53	48

Conclusions

1. Using selective coatings it is possible to significantly expand the effective temperature range of water heaters.

2. From the variants of existing selective coatings examined coating a polished copper boiler with a cobalt dioxide film and coating the protective glass with tin dioxide is optimal for the case of a solar water heater. The efficiency of such a solar water heater in the case of Θ_b = 100, 90, 80, 60, and 40°C, with a solar radiation of 800 kcal/m h and Θ_{env} = 30° C is η = 51, 56.5, 61, 70,

Table 3. Efficiency (%) in the case of different heating temperatures and with $\Theta_{env} = 30°C$, $I = 600$ kcal/m^{2}h.

Type of boiler receiving-surface coating	Heating temperature (t°C)							
	40	60	80	90	100	110	120	130
	Efficiency (%)							
Coated with simple black paint	69.5	45	17.5	3.5	-	-	-	-
Polished copper sheeting, coated with cobalt dioxide	74.5	58.5	41	31	21.5	11	1	-
Polished molybdenum, coated with a double film—magnesium oxide and metallic molybdenum	55	42	28	20.5	13	5	-	-
Polished aluminum sheeting coated with a copper oxide film	67.5	54	39	31	22.5	14	5.5	-
Polished copper sheeting with a layer of cobalt dioxide, and protective glass coated with a layer of tin dioxide	79	69.5	59	54	48.5	43	37	31.5

and 78%, respectively, while for a simple solar water heater these efficiencies are η = 32, 40, 47.5, 61, and 73.5%.

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